

companies to strike a fair balance between minimizing the initial cost of FTTC to provide conventional phone service and minimizing the total cost (initial installation plus consumer upgrade cost) to provide higher bandwidth services.

While cable television already brings a high bandwidth coaxial cable into the home, it tends to be thought of only in terms of "video in," not as a vehicle for advanced interactive services. However the basic designs of cable systems are changing rapidly in a way that may allow many companies to offer more interactive services within the next few years.

Coaxial cable can be designed for either 1-way or 2-way transmission. By some industry estimates, roughly 60 percent of all cable plant is already capable of 2-way transmission. All new cable installed since 1987 is 2-way capable.<sup>23</sup> Today's cable already has a "return channel," but it is degraded by interference and offers only a tiny bandwidth. However cable companies are beginning to deploy fiber to enlarge the channel capacity of their own systems, which would also enlarge the bandwidth capacity of the cable return channel.

Firms like Time Warner in New York and Cox Cable in San Diego are already committing to coax-fiber hybrid architectures that will let them enlarge their current capacity from about 60 to 150 channels. This increased channel capacity can also be used with 2-way capable cable to create a useful back channel out of the home. The industry is already developing "addressable" technology that allows customers to communicate in limited ways with their cable system's headend. Addressability already allows some cable viewers to select pay-per-view programming, and industry analysts project that addressability will reach over 80 percent of cable households by 1997.<sup>24</sup> Further improvements to cable TV converters (the box in the home that allows the TV set to tune the large numbers of channels available) will allow customers to select particular programming for "video-on-demand." The newest converters already have a data connection that operates at low data rates. With a coax-fiber hybrid, a converter upgrade could provide two way capability to support a computer, a video camera or any other data device.<sup>25</sup>

Cable companies are clearly migrating to some forms of limited 2-way information services. They have major advantages over telephone companies in terms of bandwidth already in place to the home and regulatory freedom to innovate and move quickly. They have disadvantages, at least at the present time, in terms of reaching fewer homes, lacking the switching capability that allows anyone to connect to anyone, and not being subject to regulatory supervision to ensure universal and affordable access by consumers and nondiscriminatory access by information providers.

In addition to fiber and cable, new developments in digital radio-based transmission technologies provide an alternative way to carry voice and data across the "last hundred feet" from the curb to the home. The telephone, cable, computer and television industries are all following these new developments with great interest.

Bellcore has set out a framework for "universal digital portable communications" that would permit wireless digital local loops with neighborhood transmitters to support handheld portable phones. Radio local loops could supplement a FTTC approach by providing a low-cost link from the curb or pedestal to individual residences. With the technology currently being considered, bandwidth would be limited to one 64 Kbps channel so that higher bandwidth services could not be provided. However, different designs could support different bandwidths in and out of the home and higher bandwidth is not technically difficult to provide over short distances provided the potential for interference with adjacent frequencies (such as television stations) can be dealt with. Issues for further study are the technical capabilities and costs involved in higher bandwidth radio loops and the spectrum allocations required by the emergence of local radio loops.

Cable companies see another kind of opportunity because radio loops or personal communication networks (PCNs) can be connected to switches. Some cable firms are exploring the possibility that PCN technology may be the best technical approach to allow them to migrate toward the switching capabilities that only telephone companies possess today. A number of FCC licenses have already been granted for this kind of experiment.

Computer companies see yet another possibility. Portable computers are already the fastest growing part of the PC market. Truly "portable" computers with wireless radio connections and improved battery technology are considered the biggest potential new development in the industry. Many analysts believe the "portability" factor has been underestimated in the past. When people have to "sit down in front of a computer" to do something they are less likely to do it than if they can pull it out of their purse, curl up with it in an easy chair -- use it, in effect, much more like a book or magazine.<sup>26</sup>

Broadcast television companies have still a different interest. As long as TV has been analog, it made sense to broadcast from a central antenna. Because of the declining price of chips, digital TV is looking increasingly practical. Several of the alternative approaches to HDTV now before the FCC are digital. One problem with digital, however, is that it could cut off people in marginal reception areas. With digital, you "either get it or you don't," unlike analog where you get a faded signal but still get it. This characteristic of digital favors shifting from one large central antenna to many, small antennas -- the same kind of configuration being considered for telephone and cable.<sup>27</sup>

Finally, local radio loop and satellite technologies will soon be used to add interactive features to conventional broadcast or cable television. In such systems, for example, TV programming schedules would be downloaded by satellite to local distribution centers which would send the schedules to local homes for display on the TV screen. Consumers could respond to polls, order products, or select pay-per-view programming by using a simple remote control device to respond to menus presented on the screen.<sup>28</sup>

In most instances, the comparative costs of these various approaches are not well understood. An important issue for further study is whether mass economies of scale are possible quickly through the convergence of different industries on radio loop technology and what impact these economies of scale would have on the cost of bringing broadband into the home.

It is clear that each of these alternative approaches to bringing advanced health care, education and other services into the home carry very specific regulatory and economic implications. The regulatory environment for these various approaches differs as respects the freedom to innovate, the availability requirements of capital, incentives for the development of consumer services, and the degree of affordable universal access which each would provide for consumers.

## DEMAND FOR RESIDENTIAL BROADBAND NETWORKS

One of the issues we have attempted to clarify in this study is whether the more advanced residential applications being conceived today can be done with only minor modifications of the existing infrastructure or whether they require a new generation of residential broadband communication networks.

Our analysis concludes that broadband, fully interactive switched networks are essential to develop if the public is to benefit from the full range of advanced health care and educational telecommunications services that new technologies will make possible.

However, as we have discussed above, there are significant cost differences as you go up the bandwidth scale. Broadband networks will be expensive to put in place. A possible first phase step might be to deploy network upgrades to achieve a 1.5 mbps bandwidth into the home. This bandwidth could handle many of the applications into the home including VCR quality video images. It could also handle simultaneous data and voice transmissions which would enable consumers to use both capabilities at the same time over the same line, which they cannot do today either with facsimile or with their PCs.

A historic debate is underway today in both government and the private sector, first as to whether active government intervention is necessary to deploy a high bandwidth network prior to 2040, and second, whether the economic and social benefits of accelerated network deployment will exceed the costs. Questions are also raised about how to insure that deployment occurs in such a manner that the public is equitably benefitted. Without government regulation, it seems unlikely that consumers, school boards and health care facilities in rural, inner city and less affluent neighborhoods will be able to participate in the new advanced telecommunications services in the same time frames as their more affluent counterparts in more populous districts.

The debate has centered on the evolution of the private network system and the public switched telephone network, but it is broadening to include the potential role of cable TV and other networks.

At one pole of this debate, enthusiastic "supply-siders" are confident that if we actively intervene to accelerate the deployment of new digital fiber optic and switching technologies, information provider entrepreneurs will begin to quickly find new consumer applications for these networks -- "build it and they will come." At the other pole, cautious "demand-siders" argue that we should leave it to the market, which will invest in new network capacities when clear needs and immediate demands are pressing us to respond. The demand-siders appear to have been getting the better part of this argument in recent years.

Between the supply-siders' faith and the demand-siders' skepticism, there is room for disciplined speculation about future residential communications activities. This is the approach we have used in this report.

Most previous demand studies have been limited to readily identifiable mass markets for one-way broadband services. For example, a recent RAND study of future demand concluded that there is unlikely to be sufficient residential demand to justify the required local network investment costs. However, the study focused almost exclusively on "video jukebox," a switched service that allows subscribers to make individual choices of video programming from among a telephone company's library of videos. The study assumed that video jukebox is the only significant broadband service that telephone companies might provide that is not already available on cable.<sup>29</sup>

This leaves out of the picture all the home learning and health applications we have examined, as well as many other types of home information services such as telecommuting, home shopping and home banking which are also the focus of increased consumer interest and activity.

We believe that the more extreme "demand siders" fail to grapple with the fundamental chicken and egg dilemma which inheres in any attempt to predict market demand for new technology services. Without the development of services by information providers, consumers cannot exercise any real choice or signal their interests or desires for any new, advanced services. As a result, efforts to forecast consumer demand must be inherently flawed and largely guess work.<sup>30</sup>

The workshop participants who reviewed our initial draft thought that if no special action were taken, the public network might drift towards providing one way 1.5 mbps video plus two way voice by the late 1990s. Cable will also achieve more interactive capabilities in the same time frame. It is often estimated that, at current deployment rates, it could take until roughly 2040 before a true broadband fiber optic network is fully deployed. The earliest target date suggested for an accelerated deployment of fiber optics in the public network is 2015. Thus we are talking about a significant time lag: two generations of the public will be impacted by whether or not network deployment is accelerated.

The issue for public policy decision makers and industry and consumer leaders is whether these likely incremental network developments are acceptable or whether there is a need for public policy decision makers to intervene and push the deployment of a high bandwidth fiber network in an earlier time frame. A key question is whether continued investments in "enhancing" existing copper lines could actually retard investment in a true fiber based broadband network. Another key question is an appraisal of the significant public and social values which can be realized from a broadband network infrastructure. Our research suggests that it is especially important to examine the potential of home learning and health applications to respond to the needs of the country for educational reform and more efficient and equitable health care access.

Our conclusion from this study is that the potential benefits of advanced learning and health applications are far larger than is usually appreciated. Advanced home services that support and amplify positive developments like active and cooperative learning or disease prevention and health promotion can transform the way we learn and reshape our approach to health care. While there is a tendency to overestimate what is possible in the next few years (the "hype" factor), there is also a tendency to seriously underestimate what will be possible over a generation -- the time frame in which broadband networks can reach into homes.

The public needs to better understand the benefits advanced learning and health services could provide for them. And our policy makers need to more fully analyze the important cost and social benefit tradeoffs involved in deciding whether and in what time frame to accelerate the evolution of broadband networks to the home.

This study is part of a larger joint effort by the Consumer Interest Research Institute and the Institute for Alternative Futures to clarify the technical and policy choices for making advanced information services available to the public in a useful, accessible, affordable and timely manner. Future papers and dialogues with public policy decision makers, health care and educational professionals, information providers and industry and consumer leaders will be necessary to analyze the benefits to industry and society of a more educated and healthier work force and citizenry, and to identify the regulatory and economic implications of the various technology options. It will be critical to make some relatively firm estimates as to whether an interim 1.5 mbps bandwidth network would yield a critical mass of services to make this a viable and practical first phase goal. Finally, many issues surrounding cost efficiencies of various technology alternatives, feasible and equitable funding mechanisms, the need for regulatory structures, consumer willingness to pay for different types of services, equitable access to low income and rural consumers, and privacy also surfaced during our discussions and require separate attention.

## NOTES

1. Examples of studies of health and information technology by IAF and its for-profit subsidiary Alternative Futures Associates include Clement Bezold, Rick Carlson, and Jonathan Peck, The Future of Work and Health (Dover, Massachusetts: Auburn House, 1986); Jonathan Peck and Kenneth Rabin, Regulating Change: The Future of Food, Drug and Cosmetic Law, (Washington: The Food and Drug Law Institute, 1990); Health Care 2010: the U.S., Europe and Japan; Aging in 2040; Alternative Futures, a report for the New Roles in Society Project of AARP; The Future of Aging and Self Care: A Four Country Study; and "Self Care 2010". Studies of education and information technology include Robert Olson and Clement Bezold, The Future of Lifelong Education, for the New Roles in Society program of the American Association of Retired Persons, 1990; Robert Olson, "The Electronic College: How Technology Will Transform the Way We Learn" for the Electronic College Conference, Virginia Military Institute, 1990; and "Information Technology in Education" for the George Washington University Seminar on the Information Age, 1989.
2. Special thanks for participating in lengthy interviews and providing materials for our use to Richard Binder, National Corporation for Research Initiatives; Alan Daley, Bell Atlantic; Chris Dede, George Mason University; Michael McDonald, Windom Health Systems; Lee McKnight, MIT; James Mecklenberger, National School Board Association; Bob Thompson, University of North Carolina Medical School; Peter Tolos, The Center for Medical Informatics; Gary Watts, National Education Association; and Barry Zallen, Harvard Community Health Plan.
3. See Alan C. Kay, "Computer, Networks and Education", Scientific American (September 1991), pp 138-148. Kay reviews shifts in assumptions about the nature of learning and emphasizes that while information technology can transform the way we learn, it will only do so when combined with a more advanced pedagogy.
4. Good reviews of emerging learning technologies include Research and Technology Development on Telematic Systems for Flexible and Distance Learning, Brussels, Belgium: Commission of the European Community, 1990; Educational Technology, NEA Special Committee Report, Washington, National Education Association, 1990; Linking for Learning, Washington, Congressional Office of Technology Assessment, 1989; Power On, Congressional Office of Technology Assessment, 1988; Christopher Dede, "Emerging Information Technologies: Implications for Distance Learning", Annals of the American Academy of Arts and Sciences, March 1991; Christopher Dede, "Restructuring Learning with Technology", Bank Street College of Education, 1990.
5. The term "knowbots" is trademarked by the National Corporation for Research Initiatives which is developing prototypes of knowbot software.

6. Christopher Dede, "The Evolution of Distance Learning: Technology-mediated Interactive Learning", Journal of Research on Computerizing in Education, Vol. 22, No. 3, Spring 1990.
7. Stewart Brand develops the concept of "broadcatch" in his book, The Media Lab: Inventing the Future at MIT, New York: Viking, 1987.
8. The image of advanced home health care presented in this section is based principally on forecasts by the Institute for Alternative Futures. It also reflects interviews with Michael McDonald, Windom Health Systems; Dr. Barry Zallen, Harvard Community Health Plan; Bob G. Thompson, University of North Carolina Medical School; and Peter Tolos, The Center for Medical Informatics. Other sources include the testimony of Dr. Barry Gilbert, of the Mayo Clinic Foundation, to the FCC hearing on the future of the telecommunications: "Applications of Broadband Switched Digital Networks to the Practice of Medicine and Delivery of Health Care"; a summary of new products from Interpractice Enterprises; issues of the Medical Documentation Update published by the Medical Records Institute; and "Healthcare for an Aging America: The Role of Telecommunications", remarks by Mary Gardiner Jones to the National Engineering Consortium.
9. There are other network features which will be important in terms of cost and speed of access. For example, improvements in processors make it possible to connect disparate devices through conversion between protocols, voice-to-text, English to Japanese, etc. Memory is also critical for functions such as storing multimedia databases and allowing simultaneous access by multiple parties needing to view the same material.
10. We are only discussing narrowband ISDN as an enhancement of the copper line and not broadband ISDN which requires a fiber network.
11. Interview with Lee Eichmann, AT&T.
12. Deloitte & Touche, New Jersey Telecommunications Infrastructure Study, Vol. III, January 1991, pp. IX-35.
13. James Martin, "The State of Technology in the Second Decade of the 21st Century", PC Week, November 21, 1988, p.41.
14. Stewart Brand quotes Andy Lippman of the Media Lab extensively on the definition of interactivity in The Media Lab, pp. 46-50.
15. Deloitte & Touche, p. IX-10.
16. Ian M. Ross, President of AT&T Bell Laboratories, "Telecommunications Technology: Trends and Implications", keynote address for publication in the Conference Proceedings of the 1988 Bicentennial Engineering Conference, Sydney, Australia, February 23, 1988.

17. Thomas C. Miller, "SONET and BISDN: A Marriage of Technologies", Telephony, May 15, 1989.
18. Perspectives for Advanced Communications in Europe, Vol. 2, Brussels, Belgium: Commission on the European Community, 1990, section 5.1.3, p. 3.
19. Interview with Irwin Dorros, Vice President, Bell Communications Research.
20. Perspectives for Advanced Communications in Europe: Summary Report, Brussels, Belgium: Commission on the European Community, 1990, p. 13.
21. Barry K. Gilbert of the Mayo Foundation in Rochester, Minnesota cites inexpensive gallium arsenide chips in development (Rockwell/Mayo) with greater than 100 Gigabit/second data processing capability at 6-10 GHz. See his unpublished paper "Impacts of a Future U.S. Wideband Switched Digital Communications System on the Health Care Delivery System in the Year 2000-2010 Time Frame", May 1991.
22. Deloitte & Touche, p. IX-33.
23. Paul Kagan Associates, Inc. Cable TV Technology, December 16, 1987, p. 5 and December 6, 1989, p. 7.
24. The Future of Television, Washington: National Cable Television Association, 1990, p. 19.
25. Interview with Richard Binder.
26. Interview with Lee McKnight.
27. Interview with Lee McKnight.
28. "TV Answer", a company in Reston, Virginia, has run a community test of a prototype interactive television system based on local radio loop and satellite technology.
29. Leland L. Johnson and David P. Reed, "Residential Broadband Services by Telephone Companies? Technology, Economics and Public Policy", RAND Corporation, June 1990.
30. Bruce L. Egan, "Business Case Analysis for Residential Broadband Communications", unpublished working draft, February 1991.